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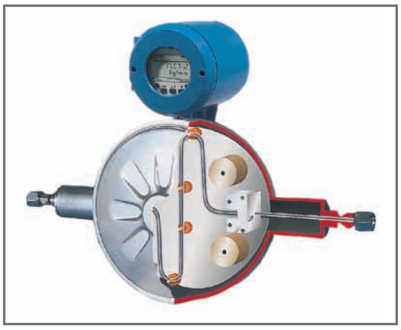

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## Improving pump performance & efficiency with composite wear components

**By Jonathan Pledger**

ELSEVIER ADVANCED TECHNOLOGY
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Condition Monitoring

# Improving pump performance & efficiency with composite wear components

**Though common, steel mating wear parts can gall and possibly eventually seize, requiring large wear ring clearances to insure the pump's rotor and stator do not touch off. Nevertheless, galling and seizing problems still plague pump users. Jonathan Pledger discusses how the use of thermoplastic composite materials can provide a greater hardness deferential between wear parts.**

For years, pump manufacturers have applied metallic parts for wear rings, sleeves, and bushings in single stage and multistage petroleum processing American Petroleum Institute (API) pumps. Since steel mating wear parts have the capacity to gall and possibly eventually seize, large wear ring clearances are required to insure the pump's rotor and stator do not touch off. Although this precaution is taken, galling and seizing problems still plague pump users during slow roll, steam turbine driven pump starts and in applications where the suction pressure of the pump is very close to the vapour pressure of the media. Even greater wear part running clearances are required when stainless steel is used due to its galling tendency. Stainless steel is required in water services and other services that would cause other steels to corrode.

In recent years, thermoplastic composite materials have been applied to either the rotating or the stationary wear part, with the mating component remaining in steel. The use of thermoplastic composite materials provides a greater hardness deferential between wear parts, the composite material serving as the sacrificial wear component.

Like all materials, there are limitations to thermoplastic composite materials as well. Yet in numerous applications, the limitations are less prominent and the gains are substantial.

## Problems due to pump recirculation

API pumps are designed and built with devices to control the amount of flow recirculation from the discharge side of the impeller back to the suction side of the impeller. These seals are referred to as wear rings. Generally they are mounted as pairs. One is mounted on the rotating impeller (impeller wear ring) and the other is mounted in the pump case (case wear ring). These wear rings also provide rotor stability.

Historically wear rings have been manufactured from various grades of steel. Friction caused by steel running on steel is so high that large wear ring clearances are required to insure the pump's rotor and stator do not touch off. Furthermore, most steel has a substantial tendency to gall when contacting mating surfaces, thus requiring additional clearance. While API 610 gives recommendations on minimum diametrical clearances for wear rings, most facilities have their own clearance charts. Many times these have been increased to try to improve reliability by reducing the risks of galling or seizing of pumps.

Unfortunately these large clearances lead to internal fluid recirculation with the following consequences:

- Efficiency losses — large clearances allow a greater amount of internal recirculation having a direct effect upon pump efficiency.

- Recirculation cavitation — excessive wear ring clearances can impact the tendency for formation of

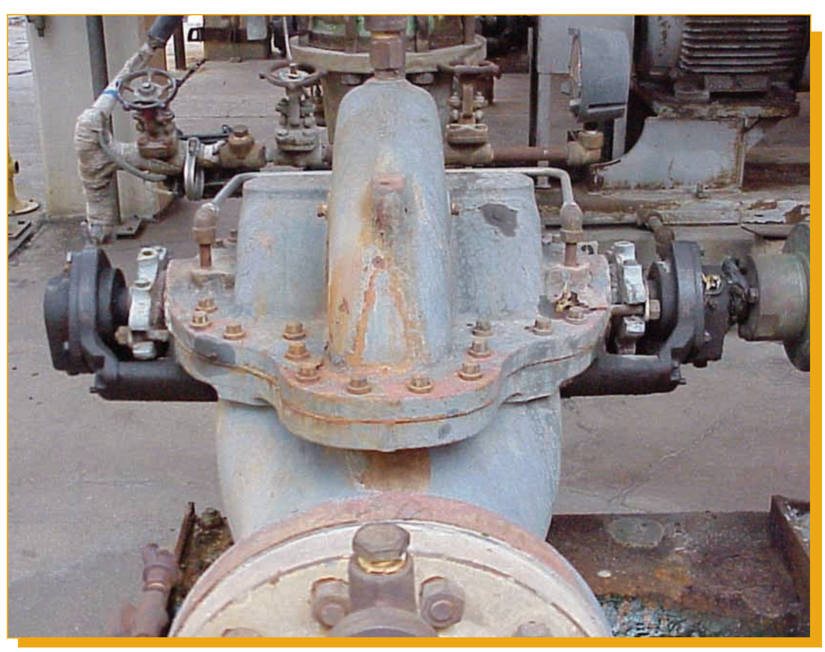

Figure 1. A double suction pump.

Figure 2. A small vertical turbine pump.

both classical and recirculation cavitation. Increased leakage across the wear ring from discharge to suction disturbs the flow pattern and can raise the NPSHR of a given impeller pattern.

- High vibration levels — the velocity of the fluid across the wear ring surfaces has a destabilising effect upon the rotor.

## Composite wear rings

Thermoplastic composite materials are non-galling, have a low coefficient of friction, and demonstrate excellent wear resistance in clean fluids. More recently, carbon fibre reinforced, high performance thermoplastic composites have been developed that provide mechanical properties more competitive with those of metals. As a result, these materials have been used to replace metal wear rings in a number of pump applications.

Reduced friction and galling tendencies of these performance composites allow the pump user to greatly reduce wear ring clearances. For example, Table I shows the API 610 recommended diametrical running clearances for cast iron, bronze, hardened 11 to 13% chromium, and materials with similar galling tendencies; it also lists the diametrical clearances possible with the WR materials.

**TABLE 1**

| Diameter of Rotating Member at Clearance Joint (Inches) | Minimum Diametrical Clearance (Inches) | |
|---|---|---|
| | API 610 | Clearance using w525* |
| 4.500 to 4.999 | .016 | .006 |
| 5.000 to 5.999 | .017 | .006 |
| 6.000 to 6.999 | .018 | .007 |
| 7.000 to 7.999 | .019 | .008 |
| 8.000 to 8.999 | .020 | .009 |

*Greene, Tweed & Co. WR® composite material

The benefits of reducing the diametrical running clearances on pump wear parts include:

- Pumps operating at greater efficiency-reduction in internal recirculation that reduces horsepower
- Recirculation cavitation opportunity is minimised
- Reduction of vibration levels

These enhancements in performance translate into tangible returns. For example, a pump OEM repair shop upgraded a 9-stage horizontal split case boiler feed water pump from stainless steel impeller wear rings and sleeves to continuous carbon fibre, thermoplastic composite components. This pump has been in service for over two years with no loss of efficiency gains. The pump particulars are as follows:

| | |
|---|---|
| Capacity: | 2200 GPM |
| Differential Head: | 5100 ft. |
| Specific Gravity: | 0.96 |
| Delta 'P': | 2119 PSIG |

Pump efficiency increased from 81.2% to 83%. Based on electricity cost for the region of $0.12kW/hr, savings resulted in $57,248 per year. The overall cost to pull, transport, repair, and reinstall the pump was $30,000, so the pump user achieved payback in 6.3 months.

In a second example, two horizontal split case pumps (300 hp 8-stage and 200 hp 4-stage) running diesel fuel and gasoline at ambient temperature were retrofitted with composite case wear rings and bushings. The original bronze components were replaced with components made from a carbon fibre reinforced thermoplastic.

Replacement of the wear rings and bushings with low friction, non-galling material allowed the tolerances to be reduced from API clearances to .0015 inch/inch on rotating diameter. The impact on vertical vibrations was substantial. Vibrations on the four-stage pump were reduced from .525in/sec to 0.084in/sec. Vibrations on the 8-stage were reduced from .600in/sec to .094in/sec. For both pumps, vibrations were reduced 84%. These pipeline pumps have now been in service for over three years.

## Galling and seizing of pumps

As long as there is metal wearing on metal, there is an opportunity for galling and seizing of wear components and pumps. In high corrosion environments this problem is greatly magnified since stainless steel components are required, which are prone to galling. There are many causes for wear parts rubbing, even when large diametrical clearances are used. Among these causes are:

Figure 3. A large vertical turbine pump.

### Radial bearing failure

When a radial bearing fails this allows the rotor to drop and the wear components to come into hard contact. This scenario often leads to severe galling and complete pump seizure.

### Product vaporisation

When a pump suffers traditional cavitation there is a definite opportunity to loose the lift generated by the hydrodynamic film created by the fluid thereby allowing the rotor to drop and the wear surfaces to rub.

### Shaft deflection

Excessive shaft deflection is another cause of wear components coming in contact with one another. When a centrifugal pump operates away from its best efficiency point a radial force is generated that will attempt to bend the shaft. This can cause a rotating component such as a wear ring or mechanical seal to contact a stationary component causing damage to either or both of them.

### Slow roll starts required by pumps being steam turbine driven

This problem is especially evident in larger multistage horizontal pumps where the rotor must achieve a certain speed to get adequate lift — otherwise the wear components in the pump are contacting.

### Lack of radial bearing support

This problem is prevalent in older model double suction pumps (see figure 1) and 2-stage overhung pumps. When these pumps were originally designed, they were sealed with rope packing that provided radial bearing support for the shaft. But due to more stringent emission standards, many of these pumps have been converted to mechanical seals. The loss of the packing bearing support leads to greater shaft deflection, short mechanical seal life, and possible wear ring galling.

## Reducing galling and seizure

Though there are many things that may be done to minimise the possibility of galling and seizing of pumps, there is one consistent way to avoid this concern. That is to use non-galling, non-seizing wear materials. High performance thermoplastic composites are available that will not gall or seize the mating steel wear components even when high load friction occurs under dry running conditions. These composites function as the sacrificial element. In a worst case scenario, these components will wear or surface melt out before galling or seizing of a rotor to the pump housing.

A great deal of technical data and research is available to demonstrate the property differences between metal and composite wear surfaces. However, there exists a large amount of field data and successes that demonstrate the practical improvements resulting from thermoplastic based wear components.

## Field success with composite components

### Radial bearing failure

A gulf coast refinery using a continuous carbon fibre, thermoplastic composite impeller wear rings in a large diameter, single stage brine water pump experienced radial and axial bearing seizure, leading to the breaking of the shaft at 1800rpm's. The composite wear ring clearances opened up to the point that they had to be replaced, but there was no wear or damage to the stainless steel impeller or case wear rings. As a result the pump repair was less than half the cost of what it would have been, if the stainless steel wear rings would have been used. The pump had been converted to composite impeller wear rings due to constant seizure of the pump using stainless steel on stainless steel wear rings.

### Product vaporisation

This type of problem often occurs in pumps moving product close to its vapour pressure such as light end hydrocarbons and boiler feed water pumps. A west Texas power plant was experiencing the seizure of three 4 x 6 x 9C, 12-stage horizontal split case, boiler feed water pumps. These pumps were operating at 266°F (130°C). Galling and seizure was occurring during short-term upset conditions where the pumps were dropping below the NPSH required. Carbon fibre reinforced thermoplastic wear inserts were installed in all stationary wear components including all case wear rings and bushings. These pumps were retrofitted and reinstalled in January of 1996 and have now been in service for over four years. The plant-engineering manager has reported that system upsets continue to plague the area, but no galling or seizing of the pumps has occurred.

### Shaft deflection

Shaft deflection causes high vibrations that shorten the life of mechanical seals and create noise. A single stage, vertical in-line pump was experiencing such a problem. Mating steel wear rings were converted to continuous carbon fibre, thermoplastic composite impeller wear rings on stainless steel case wear rings. A carbon throat bushing was also converted to a continuous carbon fibre, thermoplastic composite throat bushing. As a result, clearances were cut in half. A substantial drop in vibrations was accomplished by running tighter wear ring clearances and turning the wear rings into additional hydrodynamic bearings. Closing down of clearances was possible since the wear ring materials were constructed from a non-galling composite. This pump has now been in service for well over one year with no increase in vibrations. The tighter clearances clearly minimise shaft run out.

### Slow roll starts

When a pump is being driven by a steam turbine, often the need to get the rotor up and running at operating speed is set directly against the recommended slow roll starting warm up of the turbine. One plant was experiencing difficulties in the start up of an eight-stage 2CNTA8 boiler feed water pump. The turbine driving this pump was a single stage, 260 horse, steam turbine (60-PSI Steam). Normal speed for this turbine was from 3550 to 3600. The turbine's capabilities required that it be slow roll started at 500rpm's for approximately 30 minutes. The contact occurring between the stainless steel wear parts caused the pump to gall several times during attempted start up. The pump was retrofitted with carbon fibre reinforced thermoplastic stationary wear parts. The clearances were actually reduced having the positive effects of increasing pump efficiency and lowering vibrations, while allowing slow roll starting with no galling.

### Lack of radial bearing support

Short mechanical seal life as well as galling problems have been solved on many double suction pumps as well as in many 2-stage overhung pumps. On double suction pumps thermoplastic composites have been applied very often as tight running case wear rings as well as in throat bushings in both stuffing boxes when space has allowed. The small clearance case wear ring provides additional bearing support in the centre of the shaft where deflection is a problem. The use of thermoplastic composite case wear rings or impeller wear rings and throat bushings when possible has greatly improved mechanical seal life while eliminating galling. Two-stage overhung pumps are inherently predisposed to high deflections, galling, and short mechanical seal life. There are two impellers overhung with a bushing in between them but with no bearing support at the end of the shaft. Thermoplastic composite components allow the running of tight clearances on the wear rings and the bushing that is between the impellers. Shaft deflection is minimised thereby greatly improving mechanical seal life and eliminating galling.

## Fracturing of carbon and graphite alloys

Carbon and graphite alloys are sometimes used for wear components in vertical sump pumps and turbine pumps. Often, the primary driver in selecting these materials is their excellent self-lubrication properties. However, these materials are susceptible to cracking and/or fracturing. As the clearances on bushings and line shaft bearings on vertical pumps start opening up, vibrations increase and impact of shaft against the wear parts becomes more violent causing the carbon or graphite alloy parts to fracture. Also, during plant start up, many times there are solids that were not flushed out that must pass through the pumps. The velocity of the solids as they contact the wear parts will often cause damage to these brittle components.

Thermoplastic composites are available that have excellent impact resistance, in addition to being non-galling and non-seizing. Thousand of pumps retrofitted with these materials have not reported cracking or fracturing of these materials.

## Conclusion

Thermoplastic composite materials have been applied to either the rotating or the stationary wear parts in a broad range of production pumps. The use of these composite materials provides a greater hardness deferential between wear parts, the composite material serving as the sacrificial wear component. This reduces the risk of galling and seizing, thus allowing reduction in clearances that offer the following benefits: power reductions through greater pump efficiencies, lower pump vibrations, greater pump reliability through the ability to survive dry running pump episodes. These benefits result in tangible savings in the operation and repair of API pumps.

As with all materials, thermoplastic composites have their limitations. Maximum life is obtained when they are applied as wear parts in pumps moving clean media. There are also chemical compatibility limitations that should be discussed with the material manufacturer. ■

#### CONTACT

Jonathan Pledger is product manager for WR composite materials and fluid handling sales manager for Greene, Tweed and Company, a global manufacturer of seal and bearing solutions for a variety of industries including fluid handling, chemical processing, petroleum, and more.

The vertical cooling tower is one of a group that ran bronze bushings and only lasted six months. Composite wear components were installed and several of these have been in service for over three years.

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## References

1. *Nelson, W.E., 'Understanding pump cavitation', Chemical Processing (Feb 1997)*

2. *WR525 is a continuous carbon fibre polyketone composite made by Greene, Tweed & Co. It has high physical properties and low thermal expansion properties competitive with steel. This material can be applied in both tension and/or compression but most often is used for dynamic parts such as impeller wear rings and sleeves. It is generally recommended to a maximum operating temperature range of 525°F (274°C).*

3. *WR300 A proprietary polyketone and carbon fibre composite made by Greene, Tweed & Co. It has good thermal expansion characteristics, it is primarily applied as stationary wear parts such as bushings, line shaft bearings, and/or case wear rings. This material may also be applied in tension. It is generally recommended to a maximum operation temperature of 275°F (135°C).*

4. *McNally, 'Solving a major cause of shaft deflection in volute type pumps 6-5'*

5. *Greene, Tweed & Co. WR525*

6. *Greene, Tweed & Co. WR300*

7. *Greene, Tweed & Co. WR525*

8. *Greene, Tweed & Co. WR300*